



This is “Appendix A: Standard Thermodynamic Quantities for Chemical Substances at 25°C”, appendix 1 from the book [Principles of General Chemistry \(index.html\)](#) (v. 1.0).

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Chapter 25

Appendix A: Standard Thermodynamic Quantities for Chemical Substances at 25°C

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Aluminum:			
Al(s)	0.0	0.0	28.3
Al(g)	330.0	289.4	164.6
AlCl ₃ (s)	-704.2	-628.8	109.3
Al ₂ O ₃ (s)	-1675.7	-1582.3	50.9
Barium:			
Ba(s)	0.0	0.0	62.5
Ba(g)	180.0	146.0	170.2
BaO(s)	-548.0	-520.3	72.1
BaCO ₃ (s)	-1213.0	-1134.4	112.1
BaSO ₄ (s)	-1473.2	-1362.2	132.2
Beryllium:			
Be(s)	0.0	0.0	9.5
Be(g)	324.0	286.6	136.3
Be(OH) ₂ (s)	-902.5	-815.0	45.5
BeO(s)	-609.4	-580.1	13.8
Bismuth:			
Bi(s)	0.0	0.0	56.7
Bi(g)	207.1	168.2	187.0
Bromine:			
Br(g)	111.9	82.4	175.0
Br ₂ (l)	0.0	0.0	152.2
Br ⁻ (aq)	-121.6	-104.0	82.4

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Br ₂ (g)	30.9	3.1	245.5
HBr(g)	-36.3	-53.4	198.7
HBr(aq)	-121.6	-104.0	82.4
Cadmium:			
Cd(s)	0.0	0.0	51.8
Cd(g)	111.8	—	167.7
CdCl ₂ (s)	-391.5	-343.9	115.3
CdS(s)	-161.9	-156.5	64.9
Calcium:			
Ca(s)	0.0	0.0	41.6
Ca(g)	177.8	144.0	154.9
CaCl ₂ (s)	-795.4	-748.8	108.4
CaF ₂ (s)	-1228.0	-1175.6	68.5
Ca(OH) ₂ (s)	-985.2	-897.5	83.4
CaO(s)	-634.9	-603.3	38.1
CaSO ₄ (s)	-1434.5	-1322.0	106.5
CaCO ₃ (s, calcite)	-1207.6	-1129.1	91.7
CaCO ₃ (s, aragonite)	-1207.8	-1128.2	88.0
Carbon:			
C(s, graphite)	0.0	0.0	5.7
C(s, diamond)	1.9	2.9	2.4
C(s, fullerene—C ₆₀)	2327.0	2302.0	426.0
C(s, fullerene—C ₇₀)	2555.0	2537.0	464.0
C(g)	716.7	671.3	158.1
C(g, fullerene—C ₆₀)	2502.0	2442.0	544.0
C(g, fullerene—C ₇₀)	2755.0	2692.0	614.0
CBr ₄ (s)	29.4	47.7	212.5
CBr ₄ (g)	83.9	67.0	358.1
CCl ₂ F ₂ (g)	-477.4	-439.4	300.8

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
CCl ₂ O(g)	-219.1	-204.9	283.5
CCl ₄ (l)	-128.2	-62.6	216.2
CCl ₄ (g)	-95.7	-53.6	309.9
CF ₄ (g)	-933.6	-888.3	261.6
CHCl ₃ (l)	-134.1	-73.7	201.7
CHCl ₃ (g)	-102.7	6.0	295.7
CH ₂ Cl ₂ (l)	-124.2	—	177.8
CH ₂ Cl ₂ (g)	-95.4	-68.9	270.2
CH ₃ Cl(g)	-81.9	-58.5	234.6
CH ₄ (g)	-74.6	-50.5	186.3
CH ₃ COOH(l)	-484.3	-389.9	159.8
CH ₃ OH(l)	-239.2	-166.6	126.8
CH ₃ OH(g)	-201.0	-162.3	239.9
CH ₃ NH ₂ (l)	-47.3	35.7	150.2
CH ₃ NH ₂ (g)	-22.5	32.7	242.9
CH ₃ CN(l)	40.6	86.5	149.6
CH ₃ CN(g)	74.0	91.9	243.4
CO(g)	-110.5	-137.2	197.7
CO ₂ (g)	-393.5	-394.4	213.8
CS ₂ (l)	89.0	64.6	151.3
CS ₂ (g)	116.7	67.1	237.8
C ₂ H ₂ (g)	227.4	209.9	200.9
C ₂ H ₄ (g)	52.4	68.4	219.3
C ₂ H ₆ (g)	-84.0	-32.0	229.2
C ₃ H ₈ (g)	-103.8	-23.4	270.3
C ₃ H ₆ O ₃ (s) (lactic acid)	-694.1	-522.9	142.3
C ₆ H ₆ (l)	49.1	124.5	173.4
C ₆ H ₆ (g)	82.9	129.7	269.2

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
C ₆ H ₁₂ O ₆ (s) (glucose)	-1273.3	-910.4	212.1
C ₂ H ₅ OH(l)	-277.6	-174.8	160.7
C ₂ H ₅ OH(g)	-234.8	-167.9	281.6
(CH ₃) ₂ O(l)	-203.3	—	—
(CH ₃) ₂ O(g)	-184.1	-112.6	266.4
CH ₃ CO ₂ ⁻ (aq)	-486.0	-369.3	86.6
<i>n</i> -C ₁₂ H ₂₆ (l) (dodecane)	-350.9	28.1	490.6
Cesium:			
Cs(s)	0.0	0.0	85.2
Cs(g)	76.5	49.6	175.6
CsCl(s)	-443.0	-414.5	101.2
Chlorine:			
Cl(g)	121.3	105.3	165.2
Cl ₂ (g)	0.0	0.0	223.1
Cl ⁻ (aq)	-167.2	-131.2	56.5
HCl(g)	-92.3	-95.3	186.9
HCl(aq)	-167.2	-131.2	56.5
ClF ₃ (g)	-163.2	-123.0	281.6
Chromium:			
Cr(s)	0.0	0.0	23.8
Cr(g)	396.6	351.8	174.5
CrCl ₃ (s)	-556.5	-486.1	123.0
CrO ₃ (g)	-292.9	—	266.2
Cr ₂ O ₃ (s)	-1139.7	-1058.1	81.2
Cobalt:			
Co(s)	0.0	0.0	30.0
Co(g)	424.7	380.3	179.5
CoCl ₂ (s)	-312.5	-269.8	109.2
Copper:			

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Cu(s)	0.0	0.0	33.2
Cu(g)	337.4	297.7	166.4
CuCl(s)	-137.2	-119.9	86.2
CuCl ₂ (s)	-220.1	-175.7	108.1
CuO(s)	-157.3	-129.7	42.6
Cu ₂ O(s)	-168.6	-146.0	93.1
CuS(s)	-53.1	-53.6	66.5
Cu ₂ S(s)	-79.5	-86.2	120.9
CuCN(s)	96.2	111.3	84.5
Fluorine:			
F(g)	79.4	62.3	158.8
F ⁻ (aq)	-332.6	-278.8	-13.8
F ₂ (g)	0.0	0.0	202.8
HF(g)	-273.3	-275.4	173.8
HF(aq)	-332.6	-278.8	-13.8
Hydrogen:			
H(g)	218.0	203.3	114.7
H ₂ (g)	0.0	0.0	130.7
H ⁺ (aq)	0.0	0.0	0.0
Iodine:			
I(g)	106.8	70.2	180.8
I ⁻ (aq)	-55.2	-51.6	111.3
I ₂ (s)	0.0	0.0	116.1
I ₂ (g)	62.4	19.3	260.7
HI(g)	26.5	1.7	206.6
HI(aq)	-55.2	-51.6	111.3
Iron:			
Fe(s)	0.0	0.0	27.3
Fe(g)	416.3	370.7	180.5

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Fe ²⁺ (aq)	-89.1	-78.9	-137.7
Fe ³⁺ (aq)	-48.5	-4.7	-315.9
FeCl ₂ (s)	-341.8	-302.3	118.0
FeCl ₃ (s)	-399.5	-334.0	142.3
FeO(s)	-272.0	-251.4	60.7
Fe ₂ O ₃ (s)	-824.2	-742.2	87.4
Fe ₃ O ₄ (s)	-1118.4	-1015.4	146.4
FeS ₂ (s)	-178.2	-166.9	52.9
FeCO ₃ (s)	-740.6	-666.7	92.9
Lead:			
Pb(s)	0.0	0.0	64.8
Pb(g)	195.2	162.2	175.4
PbO(s, red or litharge)	-219.0	-188.9	66.5
PbO(s, yellow or massicot)	-217.3	-187.9	68.7
PbO ₂ (s)	-277.4	-217.3	68.6
PbCl ₂ (s)	-359.4	-314.1	136.0
PbS(s)	-100.4	-98.7	91.2
PbSO ₄ (s)	-920.0	-813.0	148.5
PbCO ₃ (s)	-699.1	-625.5	131.0
Pb(NO ₃) ₂ (s)	-451.9	—	—
Pb(NO ₃) ₂ (aq)	-416.3	-246.9	303.3
Lithium:			
Li(s)	0.0	0.0	29.1
Li(g)	159.3	126.6	138.8
Li ⁺ (aq)	-278.5	-293.3	13.4
LiCl(s)	-408.6	-384.4	59.3
Li ₂ O(s)	-597.9	-561.2	37.6
Magnesium:			
Mg(s)	0.0	0.0	32.7

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Mg(g)	147.1	112.5	148.6
MgCl ₂ (s)	-641.3	-591.8	89.6
MgO(s)	-601.6	-569.3	27.0
Mg(OH) ₂ (s)	-924.5	-833.5	63.2
MgSO ₄ (s)	-1284.9	-1170.6	91.6
MgS(s)	-346.0	-341.8	50.3
Manganese:			
Mn(s)	0.0	0.0	32.0
Mn(g)	280.7	238.5	173.7
MnCl ₂ (s)	-481.3	-440.5	118.2
MnO(s)	-385.2	-362.9	59.7
MnO ₂ (s)	-520.0	-465.1	53.1
KMnO ₄ (s)	-837.2	-737.6	171.7
MnO ₄ ⁻ (aq)	-541.4	-447.2	191.2
Mercury:			
Hg(l)	0.0	0.0	75.9
Hg(g)	61.4	31.8	175.0
HgCl ₂ (s)	-224.3	-178.6	146.0
Hg ₂ Cl ₂ (s)	-265.4	-210.7	191.6
HgO(s)	-90.8	-58.5	70.3
HgS(s, red)	-58.2	-50.6	82.4
Hg ₂ (g)	108.8	68.2	288.1
Molybdenum:			
Mo(s)	0.0	0.0	28.7
Mo(g)	658.1	612.5	182.0
MoO ₂ (s)	-588.9	-533.0	46.3
MoO ₃ (s)	-745.1	-668.0	77.7
Nickel:			
Ni(s)	0.0	0.0	29.9

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Ni(g)	429.7	384.5	182.2
NiCl ₂ (s)	-305.3	-259.0	97.7
Ni(OH) ₂ (s)	-529.7	-447.2	88.0
Nitrogen:			
N(g)	472.7	455.5	153.3
N ₂ (g)	0.0	0.0	191.6
NH ₃ (g)	-45.9	-16.4	192.8
NH ₄ ⁺ (aq)	-132.5	-79.3	113.4
N ₂ H ₄ (l)	50.6	149.3	121.2
N ₂ H ₄ (g)	95.4	159.4	238.5
NH ₄ Cl(s)	-314.4	-202.9	94.6
NH ₄ OH(l)	-361.2	-254.0	165.6
NH ₄ NO ₃ (s)	-365.6	-183.9	151.1
(NH ₄) ₂ SO ₄ (s)	-1180.9	-901.7	220.1
NO(g)	91.3	87.6	210.8
NO ₂ (g)	33.2	51.3	240.1
N ₂ O(g)	81.6	103.7	220.0
N ₂ O ₄ (l)	-19.5	97.5	209.2
N ₂ O ₄ (g)	11.1	99.8	304.4
HNO ₂ (g)	-79.5	-46.0	254.1
HNO ₃ (l)	-174.1	-80.7	155.6
HNO ₃ (g)	-133.9	-73.5	266.9
HNO ₃ (aq)	-207.4	-111.3	146.4
NF ₃ (g)	-132.1	-90.6	260.8
HCN(l)	108.9	125.0	112.8
HCN(g)	135.1	124.7	201.8
Osmium:			
Os(s)	0.0	0.0	32.6

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Os(g)	791.0	745.0	192.6
OsO ₄ (s)	-394.1	-304.9	143.9
OsO ₄ (g)	-337.2	-292.8	293.8
Oxygen:			
O(g)	249.2	231.7	161.1
O ₂ (g)	0.0	0.0	205.2
O ₃ (g)	142.7	163.2	238.9
OH ⁻ (aq)	-230.0	-157.2	-10.8
H ₂ O(l)	-285.8	-237.1	70.0
H ₂ O(g)	-241.8	-228.6	188.8
H ₂ O ₂ (l)	-187.8	-120.4	109.6
H ₂ O ₂ (g)	-136.3	-105.6	232.7
Phosphorus:			
P(s, white)	0.0	0.0	41.1
P(s, red) -17.6	-17.6	-12.5	22.8
P(s, black)	-39.3	—	—
P(g, white)	316.5	280.1	163.2
P ₂ (g)	144.0	103.5	218.1
P ₄ (g)	58.9	24.4	280.0
PCl ₃ (l)	-319.7	-272.3	217.1
PCl ₃ (g)	-287.0	-267.8	311.8
POCl ₃ (l)	-597.1	-520.8	222.5
POCl ₃ (g)	-558.5	-512.9	325.5
PCl ₅ (g)	-374.9	-305.0	364.6
PH ₃ (g)	5.4	13.5	210.2
H ₃ PO ₄ (s)	-1284.4	-1124.3	110.5
H ₃ PO ₄ (l)	-1271.7	-1123.6	150.8
Potassium:			

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
K(s)	0.0	0.0	64.7
K(g)	89.0	60.5	160.3
KBr(s)	-393.8	-380.7	95.9
KCl(s)	-436.5	-408.5	82.6
KClO ₃ (s)	-397.7	-296.3	143.1
K ₂ O(s)	-361.5	-322.1	94.1
K ₂ O ₂ (s)	-494.1	-425.1	102.1
KNO ₂ (s)	-369.8	-306.6	152.1
KNO ₃ (s)	-494.6	-394.9	133.1
KSCN(s)	-200.2	-178.3	124.3
K ₂ CO ₃ (s)	-1151.0	-1063.5	155.5
K ₂ SO ₄ (s)	-1437.8	-1321.4	175.6
Rubidium:			
Rb(s)	0.0	0.0	76.8
Rb(g)	80.9	53.1	170.1
RbCl(s)	-435.4	-407.8	95.9
Selenium:			
Se(s, gray)	0.0	0.0	42.4
Se(g, gray)	227.1	187.0	176.7
H ₂ Se(g)	29.7	15.9	219.0
Silicon:			
Si(s)	0.0	0.0	18.8
Si(g)	450.0	405.5	168.0
SiCl ₄ (l)	-687.0	-619.8	239.7
SiCl ₄ (g)	-657.0	-617.0	330.7
SiH ₄ (g)	34.3	56.9	204.6
SiC(s, cubic)	-65.3	-62.8	16.6
SiC(s, hexagonal)	-62.8	-60.2	16.5
Silver:			

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
Ag(s)	0.0	0.0	42.6
Ag(g)	284.9	246.0	173.0
Ag ⁺ (aq)	105.6	77.1	72.7
AgBr(s)	-100.4	-96.9	107.1
AgCl(s)	-127.0	-109.8	96.3
AgNO ₃ (s)	-124.4	-33.4	140.9
Ag ₂ O(s)	-31.1	-11.2	121.3
Ag ₂ S(s)	-32.6	-40.7	144.0
Sodium:			
Na(s)	0.0	0.0	51.3
Na(g)	107.5	77.0	153.7
Na ⁺ (aq)	-240.1	-261.9	59.0
NaF(s)	-576.6	-546.3	51.1
NaF(aq)	-572.8	-540.7	45.2
NaCl(s)	-411.2	-384.1	72.1
NaCl(aq)	-407.3	-393.1	115.5
NaBr(s)	-361.1	-349.0	86.8
NaBr(g)	-143.1	-177.1	241.2
NaBr(aq)	-361.7	-365.8	141.4
NaO ₂ (s)	-260.2	-218.4	115.9
Na ₂ O(s)	-414.2	-375.5	75.1
Na ₂ O ₂ (s)	-510.9	-447.7	95.0
NaCN(s)	-87.5	-76.4	115.6
NaNO ₃ (aq)	-447.5	-373.2	205.4
NaNO ₃ (s)	-467.9	-367.0	116.5
NaN ₃ (s)	21.7	93.8	96.9
Na ₂ CO ₃ (s)	-1130.7	-1044.4	135.0
Na ₂ SO ₄ (s)	-1387.1	-1270.2	149.6
Sulfur:			

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
S(s, rhombic)	0.0	0.0	32.1
S(g, rhombic)	277.2	236.7	167.8
SO ₂ (g)	-296.8	-300.1	248.2
SO ₃ (g)	-395.7	-371.1	256.8
SO ₄ ²⁻ (aq)	-909.3	-744.5	20.1
SOCl ₂ (g)	-212.5	-198.3	309.8
H ₂ S(g)	-20.6	-33.4	205.8
H ₂ SO ₄ (aq)	-909.3	-744.5	20.1
Tin:			
Sn(s, white)	0.0	0.0	51.2
Sn(s, gray)	-2.1	0.1	44.1
Sn(g, white)	301.2	266.2	168.5
SnCl ₄ (l)	-511.3	-440.1	258.6
SnCl ₄ (g)	-471.5	-432.2	365.8
SnO ₂ (s)	-557.6	-515.8	49.0
Titanium:			
Ti(s)	0.0	0.0	30.7
Ti(g)	473.0	428.4	180.3
TiCl ₂ (s)	-513.8	-464.4	87.4
TiCl ₃ (s)	-720.9	-653.5	139.7
TiCl ₄ (l)	-804.2	-737.2	252.3
TiCl ₄ (g)	-763.2	-726.3	353.2
TiO ₂ (s)	-944.0	-888.8	50.6
Uranium:			
U(s)	0.0	0.0	50.2
U(g)	533.0	488.4	199.8
UO ₂ (s)	-1085.0	-1031.8	77.0
UO ₂ (g)	-465.7	-471.5	274.6

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Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol K)
UF ₄ (s)	-1914.2	-1823.3	151.7
UF ₄ (g)	-1598.7	-1572.7	368.0
UF ₆ (s)	-2197.0	-2068.5	227.6
UF ₆ (g)	-2147.4	-2063.7	377.9
Vanadium:			
V(s)	0.0	0.0	28.9
V(g)	514.2	754.4	182.3
VCl ₃ (s)	-580.7	-511.2	131.0
VCl ₄ (l)	-569.4	-503.7	255.0
VCl ₄ (g)	-525.5	-492.0	362.4
V ₂ O ₅ (s)	-1550.6	-1419.5	131.0
Zinc:			
Zn(s)	0.0	0.0	41.6
Zn(g)	130.4	94.8	161.0
ZnCl ₂ (s)	-415.1	-369.4	111.5
Zn(NO ₃) ₂ (s)	-483.7	—	—
ZnS(s, sphalerite)	-206.0	-201.3	57.7
ZnSO ₄ (s)	-982.8	-871.5	110.5
Zirconium:			
Zr(s)	0.0	0.0	39.0
Zr(g)	608.8	566.5	181.4
ZrCl ₂ (s)	-502.0	-386	110
ZrCl ₄ (s)	-980.5	-889.9	181.6

Source of data: *CRC Handbook of Chemistry and Physics*, 84th Edition (2004).